Plating of 60/40 Tin/Lead Solder For Head Termination Metallurgy

By Saad K. Doss

Current head termination metallurgy consists of plated copper studs followed by plated gold pads. Gold wires are then ultrasonically bonded to the gold pads. This presentation shows the feasibility of plating tin/lead (60/40) as a replacement for the gold. This solder alloy can be lasersonically bonded to the wires. The thickness uniformity of the plated studs as a function of applied current is determined from the alpha step measurements. The maximum uniformity and smoothness of these studs are obtained at current densities between 60 and 80 mA/cm^2. The changes in thickness, uniformity, profile, and roughness of films deposited with direct and pulsed current are consistent with the expectations for pulsed plating to overcome the mass transport.

Magnetic thin-film heads used in recording disk files are connected to the read-write electronics by twisted wires. These wires have a copper core, plated with gold that is insulated by a polymer sheath. The head terminations are made of gold-plated studs. The gold wires are connected to these studs by stripping a wire zone, then ultrasonically bonding it to the stud.

This paper describes a new process for the head termination metallurgy. In this process, tin-lead (60/40) solder alloy (commercially purchased) is plated as a replacement for the gold-plated studs. This alloy is widely used in the electronic industry for interconnections and masking purposes. The effects of current density and solution composition on the deposit characteristics have been previously investigated.[1,2] In this study, the effect of direct and pulsed current on the uniformity and composition of the tin-lead-plated studs was investigated. Bath agitation and the anode/cathode design and location in the plating cell were examined as well. Moreover, lasersonic soldering was introduced for stripping the wire insulation and terminating the wire—all in one process step.[3] A special lasersonic tip was internally heated by a laser and ultrasonically vibrated. The lasersonic tip burns through the wire insulation and reflows the solder without the need for flux. This forms the electrical connection with the tin-lead-plated studs.

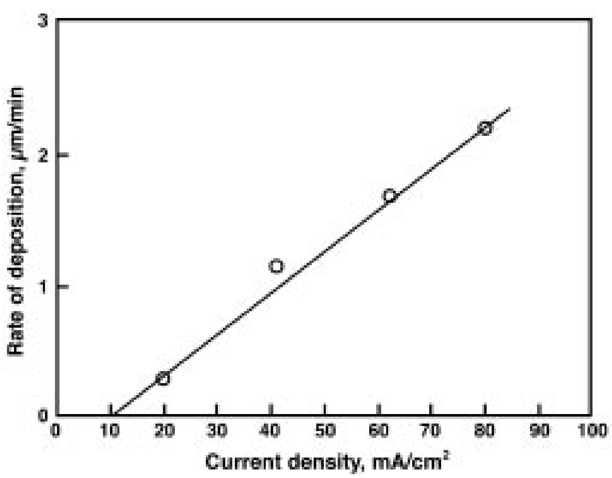

Fig. 1—Rate of deposition of tin-lead (60/40) as a function of current density.

Experimental Procedure

A commercial bath was used in this study that was a fluoborate-free, tin/lead solution. The bath make-up consisted of the following:

- Tin concentrate 12 g/L
- Lead concentrate 8 g/L
- Alkanesulfonic acid and a starter (propanol, 6 mL/L)
- Formaldehyde 3 mL/L
- Hydroquinone 0.2 mL/L

The starter acts as brightener, wetting agent and grain refiner. The 47-mm-square samples were plated in a 4-liter glass jar with a magnetic stirrer. The larger samples (5 in.) were plated in a 60-liter bath with adequate circulation (7 gal/min) and a specially designed plating cell. In this cell, both cathode and anode were placed horizontally and a specially designed paddle was used between the anode and the cathode during plating.

Sample Preparation

Non-metallic substrates, 47 mm sq and 5-in. round, were used in this investigation. These substrates were deposited with thin-film Cu seed. Photoresist was then applied, exposed and developed. A positive imaging rectangular studs resist was produced. The thickness of the resist varied between 7 and 30 µm. The stud dimensions were 230 x 200 µm and were plated with tin/lead solder alloy. The thickness of these studs varied between 5 and 30 µm.

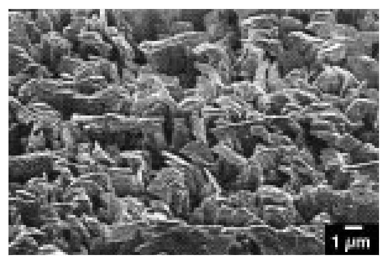

Fig. 2—Tin-lead (60/40) plated stud at 20 mA/cm^2.

Bath Operating Conditions

Various current densities, both direct and pulse, were studied, namely, 20, 40, 60 & 80 mA/cm^2. The anode material was made of tin-lead (60/40). The

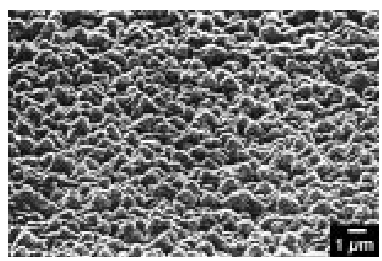

Fig. 3—Tin-lead (60/40) plated stud at 80 mA/cm^2.

cathode holder was composed of stainless steel and plastic. The bath was operated at room temperature. The tin-lead thickness was measured by Alpha step. The tin-lead composition was determined from the differential scanning calorimetry (DSC) measurements. The lasersonic bonding was done by using a laser tool with an optical fiber beam delivery, an ultrasonic bonder and a lasersonic soldering tip.

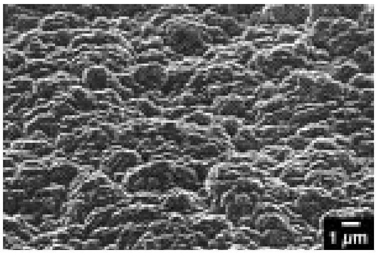

Fig. 4—Tin-lead (60/40) plated stud at 62 mA/cm², DC.

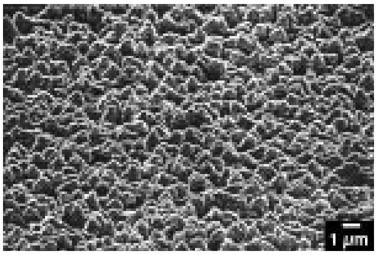

Fig. 5—Tin-lead (60/40) plated stud at 62 mA/cm², pulsed current.

Results and Discussion

A linear relationship was obtained from the tin-lead rate of deposition as a function of current density, as shown in Fig. 1. This figure indicates that the rate of deposition increases by a factor of 7 as the current density increases from 20 to 80 mA/cm^2.

The SEM photomicrographs of tin-lead-plated studs at 20 and 80 mA/cm^2 are shown in Figs. 2 and 3, respectively. The increase in current density greatly reduces the grain size of these plated studs.

The effect of direct and pulsed current on the thickness, uniformity and smoothness are shown in Figs. 4 and 5, respectively. The pulsed plating is more uniform and smooth, compared with the direct current process. These observations suggest that the mass transfer of tin and lead is limiting the rate of deposition in this range of direct current densities. This is clearly demonstrated from the Alpha step measurements (Figs. 6 and 7) where a non-uniform stud thickness that varied between 24 and 38 μm were obtained from the direct current operation (Fig. 6). The pulsed plating (Fig. 7) gave very uniform thickness with variation only between 32 and 35 μm. Moreover, the surface roughness measurements of the direct and pulsed current plating were 2 μm (p/v) and 0.6 μm (p/v), respectively (Figs. 8 and 9). Comparison of Figs. (8 and 9) with Figs. (4 and 5) shows that the diameter of the nodular growths is approximately equal to the peak-to-valley roughness. Pulsed plating is expected to produce films with finer surface texture than the films deposited with direct current at the range of current densities in which mass transport is rate-limiting. Comparison of Figs. (4 and 5) shows that the pulsed-plated films are significantly smoother than the DC films. Low surface roughness enhances lasersonic bonding because it promotes intimate contact between the pad and the wire and reduces interfacial contamination.

Hardness Measurements of Tin-Lead and Gold

Description	Hardness kg/mm^2	Depth μm
As-plated Sn-Pb	12.3	3.5
Reflowed plated Sn-Pb	21.7	2.7
Plated Au	57.6	1.7

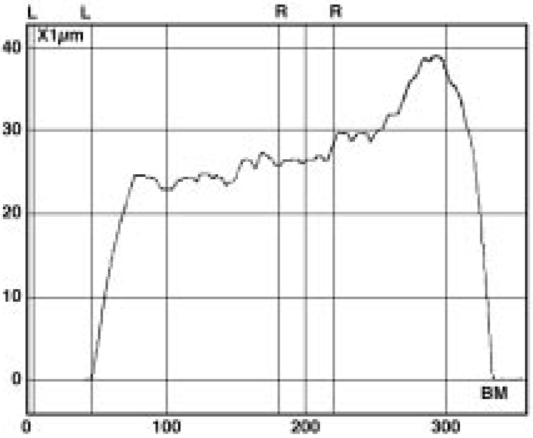

Fig. 6—Profile trace of tin-lead-plated (60/40) stud at 60 mA/cm², DC.

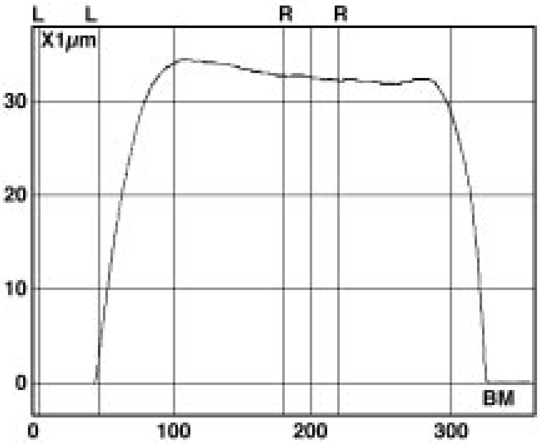

Fig. 7—Profile trace of tin-lead-plated (60/40) stud at 60 mA/cm², pulsed current.

The tin-lead compositions were calculated from the differential scanning calorimetry (DSC) measurements. The melting temperature of the 60/40 (tin/lead) anode was calculated from the DSC. The melting temperature of the direct and pulsed current terminations were similar: 184 °C and 185 °C, respectively. These numbers clearly indicated that the compositions of the direct and pulsed current are similar to the standard anode and equal 60/40 (tin/lead).

The hardness measurements (Knoop) were conducted on as-plated tin-lead, reflowed plated tin-lead, and plated gold studs, using a 10-g load. The results are summarized in the table.

The table shows that the hardness of the tin-lead is only 20 percent of the gold hardness. The reflow almost doubled the tin-lead hardness, but it was still much softer than the plated gold. A typical lasersonic soldering joint that passed the wire pull-strength test, is shown in Fig. 10.

Findings

1. Pulsed plating of tin-lead (60/40) solder alloy is superior in thickness uniformity and smoothness as compared with direct current plating, in which mass transport is rate-limiting.
2. A linear relationship is evident from the rate of tin-lead deposition as a function of current density.
3. Finer tin-lead grains are obtained with higher current densities.

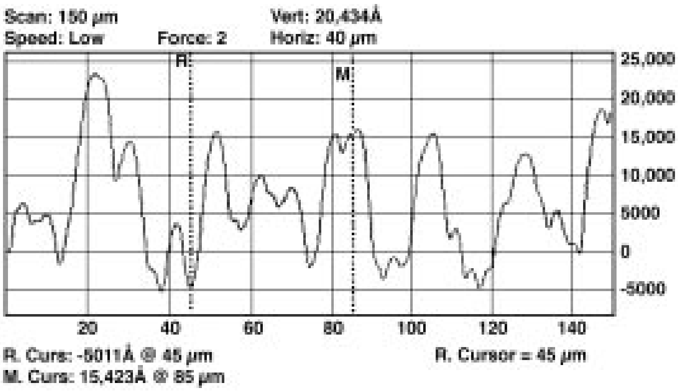

Fig. 8—Surface roughness (P/V) measurement of plated tin-lead (60/40), (60 mA/cm²) DC.

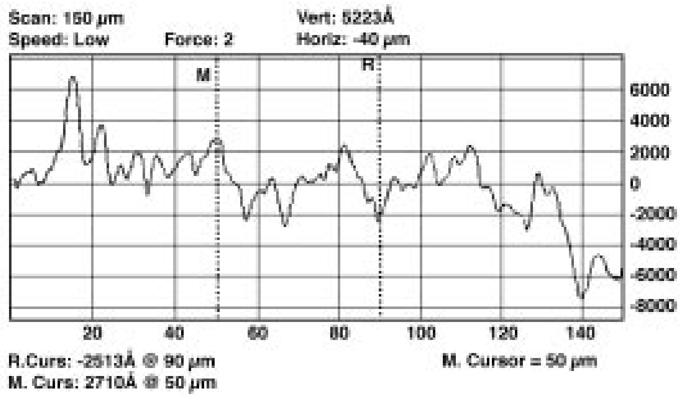

Fig. 9—Surface roughness (P/V) measurement of plated tin-lead (60/40), (60 mA/cm²) pulsed current.

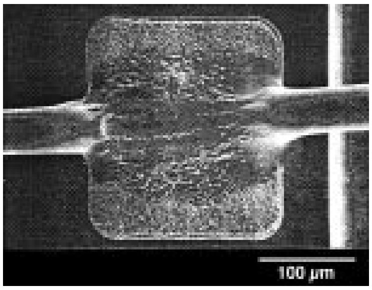

Fig. 10—Typical lasersonic soldering joint; 300X.

4. The diameter of the nodular growths is approximately equal to the peak-to-valley roughness.
5. The tin-lead composition remains constant as the current changes from direct to pulsed.
6. Plated tin-lead is much softer than plated gold.
7. Lasersonic soldering of wire to solder-plated studs was successfully demonstrated without the need to strip the wire insulation.

Editor's note: *This is an edited version of a paper presented at SUR/FIN '94, Indianapolis, IN.*

Acknowledgments

The author wishes to thank Dr. Bev Phipps for his constructive comments in reviewing this paper, and Dr. E. Lee for his suggestion to use pulsed plating in this study. Thanks are due also to M. Stout and C. Parra for their help in plating the samples, and to T. Roth for his support on the lasersonic bonding and evaluation.

References

1. Y.N. Sadana and Z.H. Zhang, *Surf. and Coat. Tech.,* **34**, 109 (1988).
2. D-T. Chin and M.K. Sunkara, *Plat. and Surf. Fin.,* **68**, 57 (Feb. 1992).
3. T.F. Roth, "Lasersonic Soldering of Head Suspension Assembly Wiring," IBM Internal Report, IBM Corp., San Jose, CA (Dec. 1992).

About the Author

Dr. Saad K. Doss is a process engineer manager with Mektec Corp., 1740 McCandless Dr., Milpitas, CA 95035. Previously, he had an extensive career with IBM in magnetic head development. He holds a PhD in materials science and engineering from the University of California at Berkeley. His technical interests include surface chemistry, anodizing, plating and chemical etching. He has been granted many patents and has published numerous papers. He was awarded the AESF Silver Medal in 1988 for an outstanding paper published in 1987.